Dec. 19, 1933. H. LIEBER 1,940,553

HEARING AID DEVICE

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Fig. 1

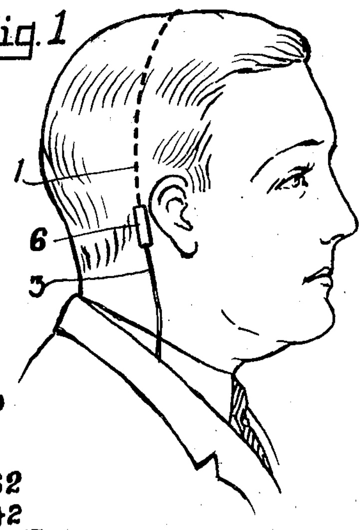
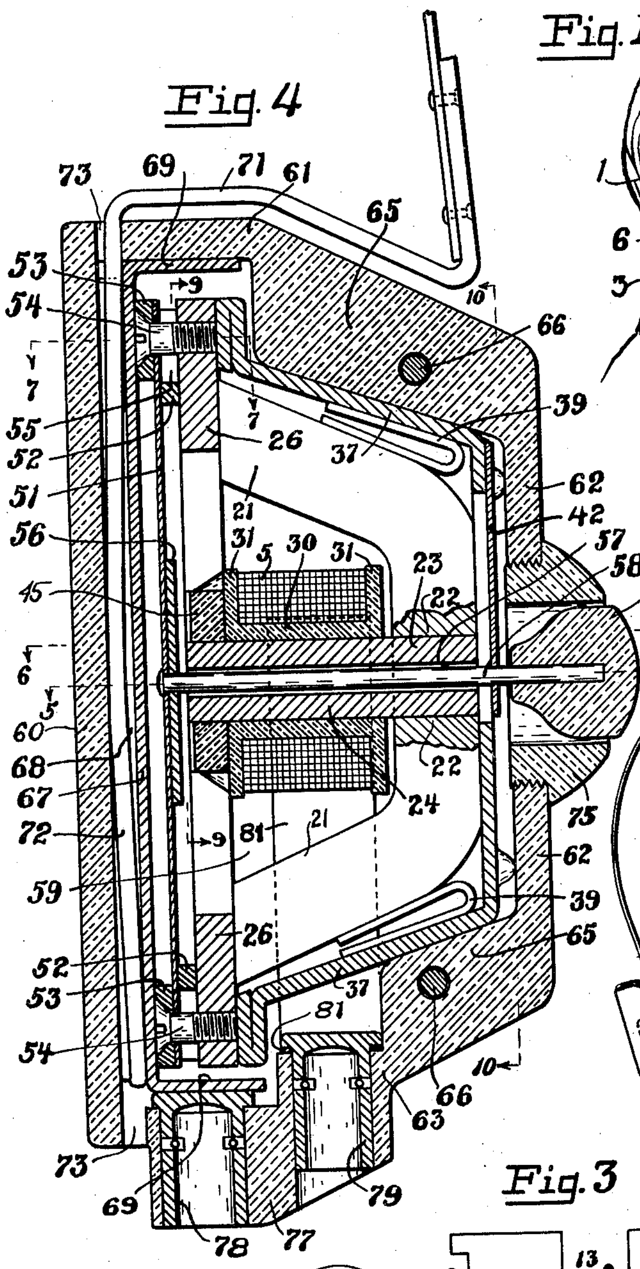


Fig. 4



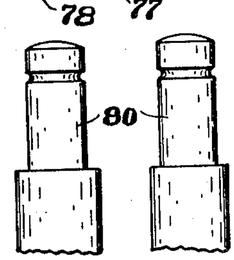


Fig. 2

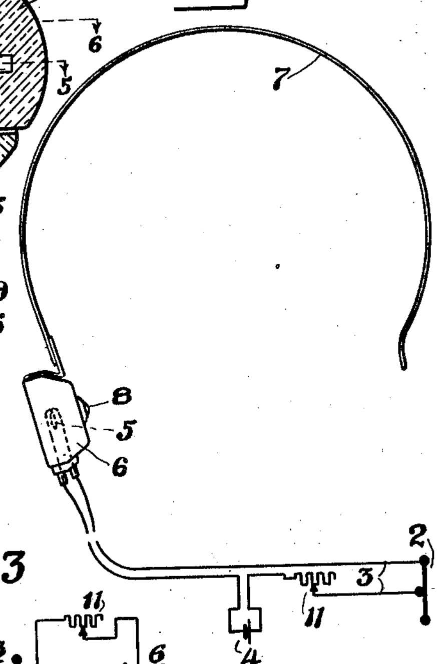
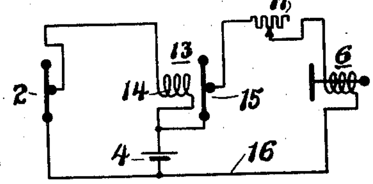


Fig. 3



INVENTOR
Hugo Lieber

BY

S M Pirnelas
ATTORNEY

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HEARING AID DEVICE

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Fig. 5.

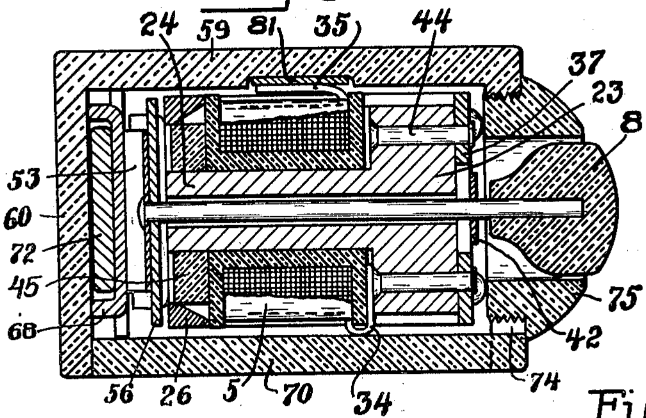


Fig. 6.

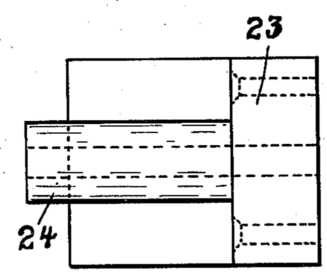


Fig. 7.

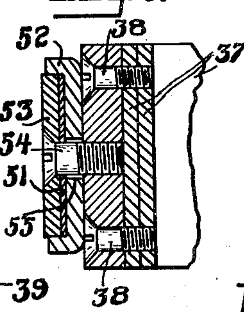


Fig. 8.

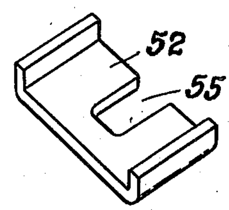


Fig. 4A.

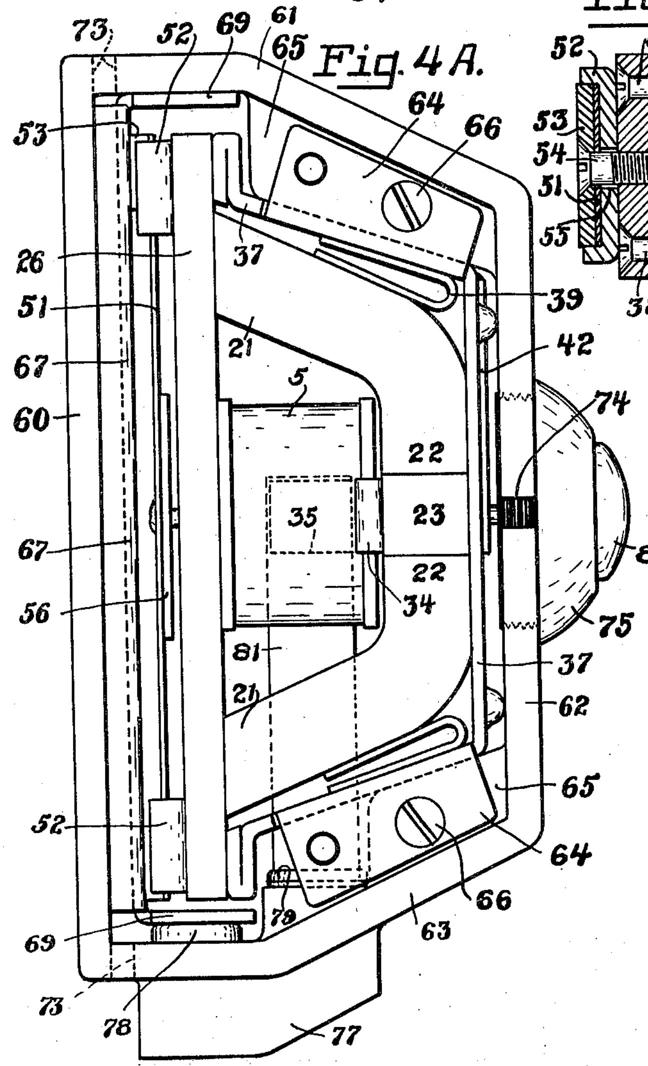
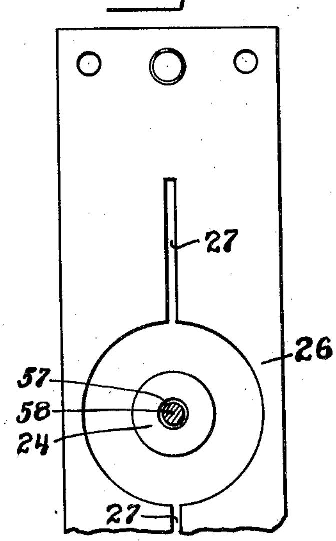


Fig. 9.



INVENTOR
Hugo Lieber

BY S M Fineles

ATTORNEY

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HEARING AID DEVICE

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Fig. 10.

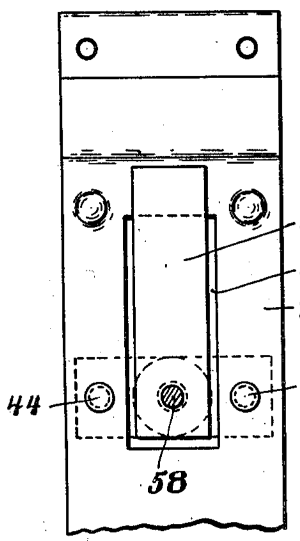


Fig. 11.

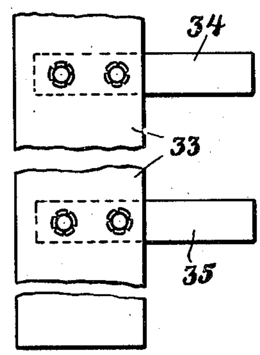


Fig. 12.

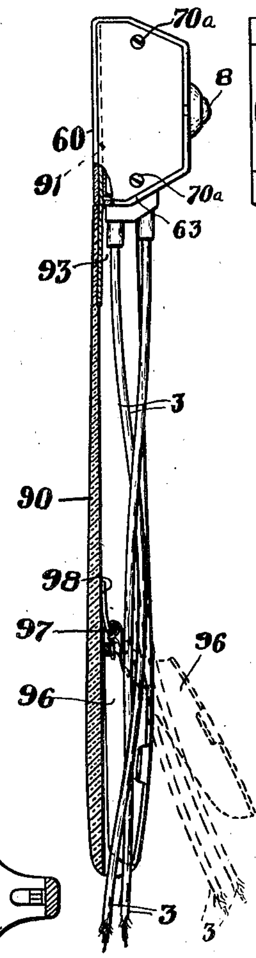


Fig. 13.

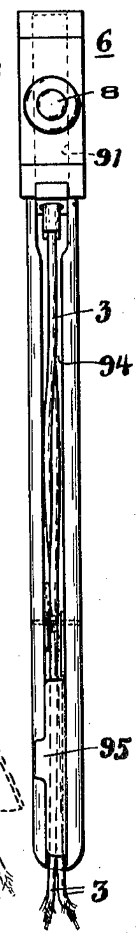


Fig. 14.

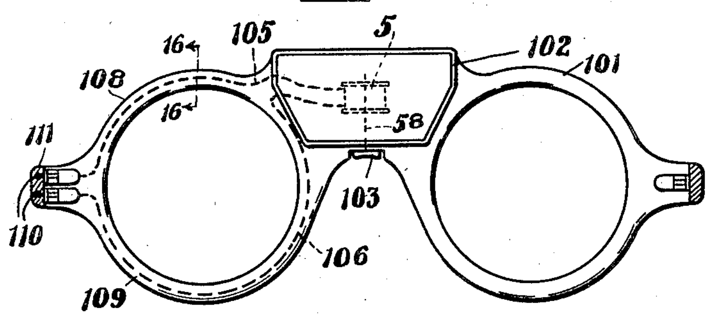


Fig. 15.

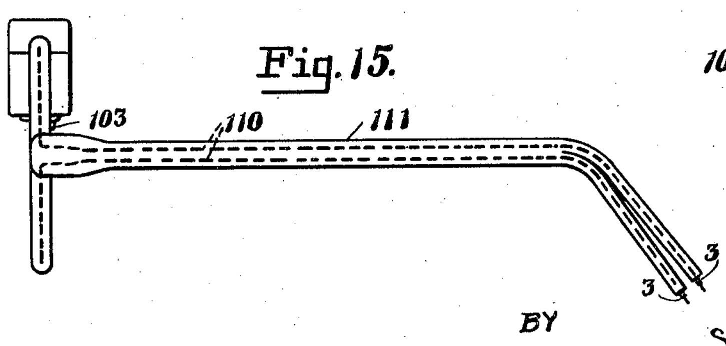
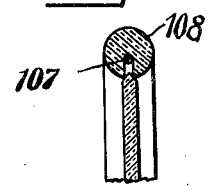


Fig. 16.



INVENTOR
Hugo Lieber

BY

S M Pineles

ATTORNEY

UNITED STATES PATENT OFFICE

1,940,553

HEARING-AID DEVICE

Hugo Lieber, New York, N. Y., assignor, by mesne assignments, to Lieber Patents Corporation, New York, N. Y., a corporation of New York

Application June 1, 1932. Serial No. 614,674

8 Claims. (Cl. 179—107)

This invention relates to hearing-aid devices, and it has among its objects the provision of an improved bone-conduction hearing-aid of small size, suitable for inconspicuous wear by hard of hearing persons, and operating with high accuracy and enough power to deliver sufficient faithfully reproduced vibratory energy to the bone structure of the head to induce corresponding loud sound sensations in the auditory nerve centers of the person.

The features and objects of the invention will be best understood from the following description and explanation of exemplifications thereof, reference being had to the accompanying drawings wherein

Fig. 1 is a view of the bone vibrator of the device as carried by a person;

Fig. 2 is a front view of the device with the associated circuit elements shown diagrammatically;

Fig. 3 is a circuit diagram of the device embodying an amplifier;

Fig. 4 is a vertical cross sectional view of the vibrator unit;

Fig. 4*a* is an elevational view of the vibrator with the cover removed;

Fig. 5 is a transverse cross sectional view of the vibrator along the line 5—5 of Fig. 4;

Fig. 6 is a transverse cross sectional view through a portion of the vibrator in Fig. 4 along the line 6—6;

Fig. 7 is a transverse cross sectional view through a portion of the vibrator along line 7—7 of Fig. 4;

Fig. 8 is a perspective view of the diaphragm adjusting blocks;

Fig. 9 is a top view of a part of the pole plate along line 9—9 of Fig. 4;

Fig. 10 is a bottom view of a vibrator portion along line 10—10 of Fig. 4;

Fig. 11 is a view of the coil strip;

Fig. 12 is a side view of a vibrator provided with a handle, with a part of the handle in section;

Fig. 13 is a front view of the vibrator and handle of Fig. 12;

Fig. 14 is a front view of a pair of spectacles provided with the vibrator of the invention;

Fig. 15 is a side view of the spectacle frame of Fig. 14; and

Fig. 16 is a cross sectional view of the spectacle frame along line 16—16 of Fig. 14.

It has been known for many years that sound conduction over the head bones is an excellent way for making many hard of hearing people hear speech and sound, although the hearing organs between their ears and auditory nerve centers are impaired. Since, in many cases, bone-conduction is the most efficient means for making a hard of hearing person hear speech and music, many efforts have been made in the past to devise a portable bone-conduction hearing-aid suitable for wearing by a hard of hearing person. However, so far none of these prior efforts have been satisfactory. These prior-art hearing-aids usually consisted of a microphone which translated the sound waves into corresponding electrical current oscillations, an amplifier for amplifying the oscillations, and an electromagnetic vibrator actuated by the electric oscillations to impart corresponding mechanical vibrations to the bone structure of the head of a person hard of hearing to produce hearing sensations in his auditory center.

It is essential that the amount of mechanical vibratory power imparted by the electromagnetic vibrator to the bone structure shall be large enough to induce in the auditory center of the head clear and intense sound sensations and secure satisfactory hearing. The vibrator employed in such aids usually consists of a movable core member attracted by a magnetic flux into contact with a complementary core body from which it is separated by a small gap through the action of resilient restraining means tending to pull the movable core member away from the core body and hold the gap open. Vibrations are imparted to the vibrator by passing amplified sound-frequency current oscillations through an inducing coil interlinked with the core, producing in the gap flux fluctuations which vibrate the movable core member, the latter transmitting the mechanical vibrations corresponding to the sound impressed on the microphone to the bone structure for conveying sound to the auditory center of the hearer.

The amount of vibratory power which can be transmitted by the vibrator increases with increase of the pole area and with decrease of the length of the air gap separating the pole faces. Since the vibrator must be small to permit its inconspicuous wear on the head, the gap area in practical devices must be held down to a low value. The only practical way in which such small vibrator may be made to develop a substantial amount of undistorted mechanical vibratory power corresponding to the impressed electrical oscillations is to decrease the air gap between the armature and pole faces. However, decrease of the air gap is accompanied by a rapid increase of the negative stiffness of the diaphragm which aids the pull of the pole faces on the armature, reducing the stability of the diaphragm unit and causing ready freezing of the armature to the pole faces and thus bringing the armature into a locked, non-vibrating position. This pole freezing danger makes it thus impractical to go to very small gaps which are necessary to enable transfer of large vibratory power in small sized vibrators. It is for this reason that the flux air gap in vibrators must ordinarily be made larger than desirable for great power output. This is particularly the case in connection with bone conduction vibrators as made heretofore, in which the body to which the vibrating contact member is applied exercises a pressure on the diaphragm in the direction toward the pole faces.

The present invention overcomes this difficulty and enables the use of smaller gaps than heretofore considered feasible in electromagnetic vibrators of this type, making possible transmission of a large vibratory power to the bones with a diminutive vibrator. This is effected by the special mounting of the vibration transmitting connection between the contact member and the armature, which is so arranged that on applying the contact member of the instrument to the head portion to which the vibrations are to be transmitted, the reaction or back pressure of the body on the contact member will automatically counterbalance any tendency to freezing of the armature, and will bring the armature into a position where its vibration transmitting action is most favorable. In this way, the electromagnetic vibrator, with a minute operating gap, liable to produce freezing, is combined with a vibration transmitting connection between the armature and the bone structure which exercises during operation a back pressure on the armature preventing freezing and sustaining stable and strong vibrations.

Because of this arrangement it is possible to make in the vibrators of the present invention the spacing of the armature from the pole faces smaller than heretofore thought possible without sacrificing the stability of the operation. The diaphragm is so constructed that when the vibrator is not applied to the body, the armature is very close to the pole faces of the core, being then near the danger zone of unstability and freezing. The length of the gap between the armature and the pole faces is then of the order of the thickness of the freezing zone. On pressing the vibrator contact against the body for transmission of the vibrations to the bones, the bone structure applies through the vibration transmitting connection a counter pressure and holds the armature in a position where the vibrating action is extremely efficient, while the danger of unstability or freezing due to excessive pole face pull is excluded.

Fig. 1 illustrates a hard of hearing person wearing the head-piece 1 of a bone-conduction hearing-aid device exemplifying the invention, the head-piece being shown in front view in Fig. 2, with the diagrammatically-indicated associated elements of the device. It comprises a microphone 2 connected through a flexible two-conductor cord 3 in series with a dry-cell battery 4 and actuating coil 5 of the bone vibrator 6 which is held by spring clip 7 on the head of the person, with the vibrator contact button 8 held against the mastoid temporal bone behind the ear. The spring clip 7 may be of wire and is bent to fit the head shape and to hold the bone vibrator under pressure against the bone. The clip wire is as a rule thin and readily disappears under the hair of the wearer, so that it is not visible.

The vibrator 6 is very small, it being about 37 millimeters long, 20 millimeters high, and 13 millimeters wide. Because of its small size the vibrator is hidden by the ear and is inconspicuous on the wearer. The microphone 2, the cord 3 and the battery 4 are also small and readily hidden in the clothing, like in the common telephone aid devices, and are likewise ordinarily unnoticeable, so that the impairment of the wearer is not readily noticed.

The microphone 2, and the battery 4 with the cord form a circuit in which electrical current oscillations are produced by speech and sound reaching the microphone, like in telephone devices. These electrical current oscillations are converted in the vibrator into mechanical vibrations imparted to the mastoid bone, and are therefrom transmitted through the bones to the auditory nerve center inducing sound sensations like those produced by sound reaching unimpaired ears. An adjustable resistor 11 serves to adjust the intensity of the current oscillations and the vibrator action.

Where increased intensity of vibrator action is desired, the vibrator 6 may be used with a booster arrangement as shown in Fig. 3, the current oscillations produced by the input microphone 2 being amplified in the microphone booster 13, through the action of coil 14 on the microphone 15 in the secondary circuit 16, and the intensified current oscillations applied to the vibrator 6 to actuate the same.

A vibrator 6 embodying the invention as actually constructed and used is shown enlarged in Figs. 4 to 11, the following description thereof and the data on the materials and the dimensions used being given herein as a guide in construction of such devices, but the invention is not in any way limited thereto.

The vibrator comprises a pair of angularly-bent permanent magnets 21 of high quality steel assembled with like poles 22 of their lower arms on opposite sides of the rectangular bottom piece 23 of a central round core member 24 of soft iron having high permeability.

The end surfaces of the outer arms of the magnets 21 abut against the underside of a flat rectangular pole plate 26 of soft, highly permeable, iron extending between the arms, making a good magnetic joint therewith. The pole plate 26 has a conically-shaped, central perforation surrounding the end of the central core, but spaced therefrom by an annular gap which is smallest at the coinciding outer levels of the pole plate and the core end to reduce leakage. Slots 27 are provided in the pole plate 26 to reduce eddy currents induced by flux changes in the space.

On the center core 24 is mounted the inducing coil 5 which is wound on a spool 30. The turns of the coil on the spool are covered by a strip 33 of varnished cloth or similar insulating material as shown in Fig. 11, wound around the coil turns and fastened in place by pasting on its end an adhesive substance, as shellack. The strip has secured thereto, by riveting or otherwise, two resilient contact strips 34 and 35, of phosphor bronze, for instance. In winding the cloth strip 33 over the turns, the end portion of the strip is wound over the portions of the two contact strips underlying the cloth strip, attaching the contact strips 34 and 35 to the opposite sides of the coil. The two ends of the coil projecting from the spool are then soldered to the projecting portions of the contact strips 34 and 35, which form terminal connections for the coil 5. As shown in Fig. 5, contact strip 34 is bent under the bottom of the spool establishing an electrical connection with the underlying portion of magnet 21; and the other contact strip 35 is insulated and bent upwardly over the coil, its spring action pressing it away from the coil.

The core members 21, 24, 26, and coil 5 are held together as a unit by a clamping strap 37 of brass, or like material, which is bent to conform to the outer contour of the assembled core members. The end portions of the strap are doubled over, to form flanges underlying the ends of the pole plate 26 and are clamped thereto by screws 38 so that all the elements are held firmly in place. To prevent the loosening of any of the elements, spring members 39, formed of doubled-over resilient metal strips, may be inserted between the outer magnet surfaces and the strap 37 to hold all the elements under pressure. To facilitate the assembly, the center core 24 has its two rectangular bottom projections 23 secured, as by rivets 44, to the bottom portion of the clamping strap 37. Insulator ring 45 holds the end of core 24 spaced from the pole plate.

As seen in Figs. 4 and 10, the flat underside of the clamping strap has a rectangular opening 41 extending from the center till near one edge thereof, and a guide strip 42 of spring metal, such as phosphor bronze, overlies the opening, having its end near the outer edge of the opening secured, as by soldering, to the adjacent strap portion, permitting free springing movement of the other strip end.

A thin resilient diaphragm 51 of hardened steel, or similar resilient material, in the form of a rectangular strip, is disposed in front of the pole plate 26 and has its ends clamped between adjusting blocks 52 and clamping blocks 53 to the ends of the pole plate 26, spaced therefrom, screws 54 threaded into holes in the pole plate ends serving to hold the blocks 52 and 53 in place. This permits free vibration of the main portion of the diaphragm 51 between the inner edges of the adjusting blocks 52, the length of the vibrating diaphragm being adjustable by shifting the adjusting blocks 52 along their slots 55 toward, or away from, the center of the pole plate.

To the underside of the diaphragm, at its center, is secured, as by soldering, a rectangular flat armature 56 of soft magnetic iron, the armature lying with its center over the pole surface of the central core 24 and with its peripheral portion over the edge portion of the surrounding pole plate 26. The height of adjusting blocks 52 and the thickness of the armature are proportioned to provide a small gap between the armature and the underlying pole surfaces of the center core 24 and the pole plate 26. The armature and the underlying pole surfaces of the center core 24 and pole plate 26 form thus two small gaps in series through which the permanent flux of the magnets 21 and the flux induced by the coil 5 passes.

The center core 24 has a longitudinal perforation 57 through which extends a vibrator rod 58 having one end fastened to the center of the diaphragm 51 and armature 56, as by soldering, and the other end projecting for a distance beyond the underside of the clamping strap, with the vibrator contact member in form of button 8 mounted thereon. The rod is confined to straight movement, out of contact with the surroundings, by the guide strip 42 on the underside of the clamping strap 37, the rod being threaded through a small hole in the freely swinging end of strip 42, and secured thereto, as by soldering.

The vibrator mechanism is housed in a casing of insulating material, like bakelite. The casing has a flat rear wall 59, and upstanding side walls 60 to 63 shaped in the interior to hold the mechanism in place, the two side arms of the clamping strap 37 being provided with wing plates 64 which are clamped to underlying casing projections 65 by screws 66, as shown in Fig. 4*a*. Opposite side wall 60 there is mounted a sheet metal partition 67 which forms with the side wall a narrow flat channel 68, the ends 69 of the partition being bent to fit into cutouts on the interior.

The side wall 62 of the casing has a slot for inserting the rod 57, the slot being covered up by a collar 72 secured in the casing wall, as by threads. On the lower side wall 63 there is provided a ledge 77 through which extend contact bushings 78 and 79 adapted to engage plugs 80 of the cord 3 to make connection with coil 5. The inner end of bushing 78 is connected to the end of the conducting partition member 67 which, in turn, is connected through the body of the core members with the bent-in contact strip 34 of the coil 5. The other bushing 79 holds at its inner end a contact plate 81 which leads along the rear wall 59 till the point opposite the outwardly pressing contact strip 35 of coil 5, making contact therewith. There is thus established a positive, conducting connection between the coil and the cord leads, permitting ready assembly and disassembly of the unit without the difficulties of soldering in the small spaces. The front side of the casing is closed by a cover 70 which fits the opening formed by the side walls, and is held in place by screws 70*a* threaded into the casing projections 65.

The wire clip 7, by means of which the vibrator is carried on the head, has on its end a flat portion 71 conforming to the outer surface of the upper side wall 64 of the casing, the spatula-like end 72 of said flat portion being inserted through the casing slot 73 into the flat channel 68 which it fits frictionally, holding the casing.

The permanent magnets 21 are of 17% cobalt steel. The center core 24 is of an iron-nickel alloy. The diaphragm is of hardened steel. The natural frequency of the diaphragm unit is about 1,000 cycles per second. The actuating coil has an impedance of 50 ohms at about 700 cycles alternating current. The two gaps have an equal length of about 2 mils when the armature is under the action of the permanent magnetic field. The assembled vibrator mechanism, without the casing, is at its longer side 3 centimeters long, at its shorter side 2 centimeters long, its height is 1.5 centimeters, and its width is .9 centimeters. The total weight of the complete vibrator unit with the casing is 16 grams and its volume is about 7.28 cubic centimeters.

When the microphone is not actuated, and no oscillatory currents flow through the actuating coil 5, only a permanent flux is induced in the armature gaps, the flux passing from the inner poles of magnets 21, through center core 24 to its upper pole face, then through the short inner gap into the armature 56, then through the armature and short outer gap into the pole face of pole plate 26, and therethrough to the outer poles of the magnets 21 of opposite polarity. Under the action of this permanent flux the diaphragm 51 with the armature 56 will be held deflected toward the pole plate reducing the gap thereto.

If sound waves impinge upon the microphone making it produce oscillatory sound currents, corresponding oscillatory fluxes are induced in the magnet core system, these oscillatory fluxes being superposed on the permanent flux and causing it to increase and decrease in accordance with the current oscillations. The resulting flux fluctuations vary the attraction exercised on the armature 56 and cause the diaphragm 51 with the elements carried thereby to vibrate in accordance with the flux oscillations. The vibratory action of the diaphragm is, in turn, imparted through rod 59 and contact button 8 to the bone against which the button is held pressed, putting the bone into corresponding vibrations which are transmitted through the bone structure of the head to the auditory organs and produce sound sensations, like those produced by the sound reaching the ears of a normal person.

As seen in Fig. 4, the pressure with which the clamping spring holds the vibrator casing against the mastoid bone, is balanced by the reactive pressure with which the bone acts on the contact member 8, causing the latter to act through rod 58 on the center of the diaphragm in a direction away from the pole surfaces, and bringing the diaphragm with its armature to a predetermined small spacing from the pole faces at which the vibratory action of the diaphragm is of high efficiency and great stability, and freezing of the armature made impossible.

The vibrator described above will, notwithstanding its small size and weight, translate sufficient electrical energy supplied by the current oscillations produced by the microphone into mechanical vibrations and impart them to the bone structure in an amount sufficient to induce in the auditory organs sound sensations of large magnitude enabling otherwise hard of hearing persons to hear speech and sound like normal persons and will not freeze nor become inoperative like prior-art small gap electric vibrators.

The vibrator diaphragm unit is made of small mass and a stiffness at which it will efficiently vibrate at frequencies within the speech range i. e. between about 60 and 1,000 cycles. The elements determining the frequency response should be proportioned to prevent variation of the vibratory power output within the speech frequency range by more than 200%. By making the natural frequency of the diaphragm unit around 1,000 cycles per second, there is obtained a very good response over the entire speech range from 50 to 1,000 cycles, and at the same time there is also secured a satisfactory response over sound range up to about 5,000 cycles enabling good reproduction of music. The natural frequency of the diaphragm unit may be made around 1,000 cycles per second and should not be made smaller. A high degree of uniformity of response is obtained by designing the actuating coil to have the optimum impedance, that is, a value about equal to the microphone impedance, at a frequency of about 700 cycles. This is attained in the device described above, by making the microphone impedance 50 ohms, and the coil impedance 50 ohms at 700 cycles, while the natural frequency of the diaphragm unit is about 1,000 cycles.

In the construction shown in Fig. 4, the diaphragm strip 51 is unstretched, and merely clamped, relying only on the rigidity of the strip for its stiffness and its restoring force to unstrained position. Such steel diaphragms of about 4 mils to 12 mils thickness combine the needed thinness with sufficient stiffness required in operation, and make it possible to proportion their action so that the forces acting when holding the vibrator against the bone, will automatically bring the diaphragm to the desired operating position at a small distance in front of the pole face where the best efficiency is obtained. Vibrators like that shown in Figs. 4 and 5 may also be built with very thin stretched diaphragms, in which case provisions are made to hold the diaphragm stretched in its position.

There are also many other advantages in the construction described. By using a strip-shaped diaphragm and a magnet system arranged longitudinally side by side, it is possible to use a relatively long diaphragm of great stiffness, thus securing stability and efficiency of operation while holding the over-all size of the unit down. The longitudinal, relatively heavy, rigid pole-plate permits quick, accurate, and simple assembly and adjustment of the diaphragm unit on one side, and of the magnet system on the other side. It also enables the use of simple permanent magnets occupying a lesser length than the pole plate, and forming only a relatively small projecting body on one side of the pole plate

Instead of using the hearing-aid device described in conjunction with Figs. 1 to 11 for transmitting vibrations to the mastoid bone, the vibrator unit with the associated elements may also be applied to any other part of the sound transmitting bone structure, such as the skull or the spinal column to impart thereto vibrations which are transmitted by the bone structure to auditory organs. In order to use the instrument in such a manner, the head clip 7 is removed and instead a special handle 90, as shown in Figs. 12 and 13, is attached to the vibrator. The handle may be made of a suitable material, such as bakelite, and has at its upper end an abutting portion fitting the lower side wall 66 of the vibrator casing. In the upper handle end is secured, as by molding, a flat spatula-like member arranged to be inserted through the lower casing slot 73 into the chamber 68 of the inner side of the longitudinal wall 60 of the casing, similar to the manner in which the end 72 of the head clip is inserted into the flat chamber 68 from the top when the head set is used. The terminal projection 77 on the underside of the casing fits into a suitable hollow space 93 within the handle 90, the handle having a longitudinal slot 94 within which the cords 3 of the instrument may be inserted. By applying the vibrator button 8, by means of the handle 90, to various bony portions of the head, for instance, to the forehead bones, vibrations are transmitted to the bone structure and therethrough to the auditory organs in the same way as with the head set arrangement described above. To permit ready removal of the handle and yet keep the cord in the hollow slot 94, the lower portion of the slot is covered by sheet metal cover 95 having on one side a projecting wall 96 extending into the slot and hinged in the interior on a transverse pin 97. A spring 98 holds cover 95 normally closed. To insert or remove the cord 3, the cover 95 is swung around its pin 97 away from the slot opening, exposing the latter.

The improved bone vibrator arrangement of my invention described above is also particularly suited for spectacle mounting as shown in Figs. 15 and 16. To this end the spectacle frame 101 is provided at its bridge portion, where it rests on the nasal bone, with an upwardly diverging casing 102 fit to receive a vibrator unit as shown in Figs. 4 and 5, the vibrating rod 58 of the vibrating unit projecting downwardly from the casing and having mounted on its end a vibratory contact member 103 shaped to fit the nasal bone. The actuating coil 5 of the vibrating unit is connected to the microphone input circuit by means of wires 105 and 106 arranged in channels 107 in the upper part 108 and the lower part 109 of the frame of one of the lenses, and thence over the hinged joint through channels 110 provided in the temple 111, to the end thereof, from where they extend in the form of a flexible cord 3 to the microphone circuit. The wires 105 going through the lens frame may be left non-insulated if these frames are of insulation material, as is usually the case.

When the spectacles are in position on the wearer's nose, the contact member 103 weighs on the nose bone. If the actuating coil 5 of the vibrating mechanism is energized with oscillatory sound currents, the vibrating unit imparts power to the contact member 103 on the nose bone, which in turn transmits this vibratory energy to the bone system and therethrough to the nerve centers. The weight of the vibrating unit is sufficient to press the contact member 103 with the required pressure against the nasal bone to impart to the bones an amount of vibratory power which will enable a deaf person to clearly hear the transmitted sound. In this arrangement, as well as in the hand portable arrangement shown in Figs. 12 and 13, the application of the instrument to the bony portion where it is to act assists in maintaining the vibrator in the stable position where its transmission of vibratory energy is most efficient.

This invention is not limited to the particular materials or details of construction pointed out in connection with the description of the specific exemplifications thereof, as many modifications and equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad construction commensurate with the scope of the invention.

I claim as my invention:

1. A hearing-aid bone vibrator for actuation by electric sound-frequency current oscillations for imparting corresponding mechanical vibrations to the sound conveying bone structure of a person and inducing corresponding sounds in his hearing organs, comprising a magnetic core having a pair of relatively movable members provided with pole faces of opposite polarity spaced by a gap and constituting a low reluctance induced flux path forcing a permanent flux through said gap, an actuating coil interlinked with said core for carrying supplied electric sound-frequency current oscillations and inducing corresponding fluctuations of flux through said gap, resilient supporting means holding said core members and constituting therewith a vibratory unit having imparted thereto by said flux fluctuations a corresponding vibratory movement relative to each other at an average gap spacing of the order of a distance which during operation is subjected to magnetic forces strong enough to freeze the adjacent pole faces to each other, and contact means actuated by said vibratory unit of said core members relative to each other to impart vibratory energy therefrom to a sound conveying bone structure of a person and for exerting during operation on said vibrating core members reactive forces preventing pulling of said core pole faces into freezing condition.

2. In a portable bone conduction hearing-aid, an electromagnetic vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conveying head-bone structure of a person and induce corresponding sounds in his auditory center, comprising a magnetic core having a pair of relatively movable members provided with relatively large pole faces of opposite polarity spaced by a gap and constituting a low reluctance induced flux path forcing a permanent flux through said gap, an actuating coil interlinked with said core for carrying supplied electric sound-frequency current oscillations and inducing corresponding fluctuations of flux through said gap, resilient supporting means holding one of said core members and constituting therewith a vibratory unit having imparted thereto by said flux fluctuations a corresponding vibratory movement at a gap distance of the order of distance at which the opposite pole faces are subjected to forces strong enough to pull the adjacent pole faces toward each other into freezing position, and a contact member having a vibration transmitting connection to said vibrating unit for imparting therefrom vibratory energy to the head-bone structure of a person and for exerting during operation on said vibrating core members reactive forces preventing pulling of said pole faces into freezing position.

3. In a portable bone conduction hearing-aid, an electromagnetic bone vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conducting bone structure of a person for inducing corresponding sounds in his hearing organs, comprising a magnetic core having a pair of relatively movable members provided with relatively large pole faces of opposite polarity spaced by a gap and constituting a low reluctance induced flux path for forcing a permanent flux through said gap, an actuating coil interlinked with said core body for carrying supplied electric sound-frequency current oscillations and inducing corresponding fluctuations of flux through said gap, resilient supporting means holding said core members and constituting therewith a vibratory unit having imparted thereto by said flux fluctuations a corresponding vibratory movement at an average gap spacing close to the distance which during operation is subjected to magnetic forces strong enough to pull said pole faces to each other into locked position, contact means for pressing against the

sound conducting bone structure of a person having a vibration transmitting connection to said vibratory unit for imparting therefrom vibratory energy to said bone structure and inducing sound in the auditory center of the person, while exerting during operation on said vibratory unit reactive forces preventing pulling said pole faces into locked position, and means for holding said vibrator and applying said contact means to the vibrated bone structure under a pressure imparting to said vibrator unit forces preventing decrease of said gap to locked position.

4. In a portable bone conduction hearing-aid, an electromagnetic bone vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conducting bone structure of a person for inducing corresponding sounds in his hearing organs, comprising a magnetic core having a pair of relatively movable core members provided with relatively large pole faces of opposite polarity spaced by a gap and constituting a low reluctance induced flux path for forcing a permanent flux through said gap, an actuating coil interlinked with said core body for carrying supplied electric sound-frequency current oscillations and inducing corresponding fluctuations of flux through said gap, resilient supporting means holding said core members and constituting therewith a vibratory unit having imparted thereto by said flux fluctuations a corresponding vibratory movement at an average gap spacing of no more than about 5 mils and of the order of the distance which during operation is subjected to magnetic forces strong enough to pull said pole faces to each other into locked position, and contact means for pressing against the sound conducting bone structure of a person having a vibration transmitting connection to said vibratory unit for imparting therefrom vibratory energy to said bone structure and inducing sound in the auditory center of the person, while exerting during operation on said vibratory unit reactive forces preventing pulling said pole faces into locked position.

5. In a portable bone conduction hearing-aid, an electromagnetic bone vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conducting bone structure of a person for inducing corresponding sounds in his hearing organs, comprising a magnetic core constituting a low reluctance magnetic path provided with a substantially coplanar pair of pole faces of opposite polarity having relatively large flux areas, a magnetic armature having a pole face facing said core pole faces and spaced therefrom by a gap, an actuating coil interlinked with said core for carrying supplied electric sound-frequency oscillations and inducing corresponding fluctuations of flux through said gap, resilient diaphragm means holding said armature and constituting therewith a vibratory unit having imparted to said armature by said flux fluctuations a corresponding vibratory movement toward and away from said core pole faces at an average gap length of the order of the distance which during operation is subjected to forces strong enough to pull said armature pole face to said core pole faces into freezing position, and contact means for pressing against the sound conducting bone structure of a person having a vibration transmitting connection to said vibratory unit for imparting therefrom vibratory energy to said bone structure and inducing sound in the auditory center of the person, while exerting during operation on said vibratory unit reactive forces preventing pulling said pole faces into freezing position.

6. In a portable bone conduction hearing-aid, an electromagnetic bone vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conducting bone structure of a person for inducing corresponding sounds in his hearing organs, comprising a magnetic core constituting a low reluctance magnetic path provided with an interior pole face of one polarity and an outer pole face of opposite polarity coplanar and symmetrical with respect to said interior pole face, a magnetic armature having a pole face facing said core pole faces and spaced therefrom by a gap, said pole faces being of substantial area to produce a large flux between the pole faces, an actuating coil interlinked with said core for carrying supplied electric sound-frequency oscillations and inducing corresponding fluctuations of flux through said gap, resilient diaphragm means holding said armature and constituting therewith a vibratory unit having imparted to said armature by said flux fluctuations a corresponding vibratory movement toward and away from said core pole faces at an average gap length close to the distance which during operation is subjected to forces strong enough to pull said armature pole face to said core pole faces into freezing position, and contact means for pressing against the sound conducting bone structure of a person having a vibration transmitting connection to said vibratory unit for imparting therefrom vibratory energy to said bone structure and inducing sound in the auditory center of the person, while exerting during operation on said vibratory unit reactive forces preventing pulling said pole faces into freezing position.

7. In a portable bone conduction hearing-aid, an electromagnetic bone vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conducting bone structure of a person for inducing corresponding sounds in his hearing organs, comprising a longitudinal magnetic core constituting a low reluctance magnetic path provided with an interior pole face of one polarity and an outer pole face portion of opposite polarity coplanar with said interior pole face, a magnetic armature having a pole face opposite said core pole faces and spaced therefrom by a gap, an actuating coil interlinked with said core for carrying supplied electric sound-frequency oscillations and inducing corresponding fluctuations of flux through said gap, a resilient diaphragm strip clamped at its ends holding said armature and constituting therewith a vibratory unit having imparted to said armature by said flux fluctuations a corresponding vibratory movement toward and away from said core pole faces at an average gap length close to the distance which during operation is subjected to forces strong enough to pull said armature pole face to said core pole faces into freezing position, and a contact member having an exposed contact surface for pressing against the sound conducting bone structure of a person and a vibration transmitting connection to said vibratory unit for imparting therefrom vibratory energy to said bone structure and inducing sound in the auditory center of the person, while

exerting during operation on said vibratory unit reactive forces preventing pulling said pole faces into freezing position.

8. In a portable bone conduction hearing-aid, an electromagnetic bone vibrator for actuation by electric sound-frequency current oscillations to impart corresponding mechanical vibrations to the sound conducting bone structure of a person for inducing corresponding sounds in his hearing organs, comprising an elongated pole plate having an intermediate opening with a surrounding flat surface constituting on one side of said plate a pole face of one polarity, a magnetic core body on the opposite side of said plate having a central permeable core member with an inner pole face lying coplanar with said outer pole face in said opening and additional core members extending between said central core member and the ends of said pole plate, a magnetic armature having a pole face facing said core pole faces and spaced therefrom by a gap to complete the flux path therebetween, an actuating coil interlinked with said central core member for carrying supplied electric sound-frequency oscillations and inducing corresponding fluctuations of flux through the flux paths of said gap, a resilient diaphragm strip supported at its ends on said pole plate and holding said armature to constitute therewith a vibratory unit subjected by said flux fluctuations to a corresponding vibratory movement at an average gap spacing close to the distance at which the magnetic forces are during operation strong enough to pull the armature pole face into freezing with the core pole faces, and a contact member having an exposed contact surface for pressing against the sound conducing bone structure of a person and a vibration transmitting connection to said vibratory unit for imparting therefrom vibratory energy to said bone structure and inducing sound in the auditory center of the person, while exerting during operation on said vibratory unit reactive forces preventing pulling said pole faces into freezing position.

HUGO LIEBER.